CANMET Gasifier Liner Coupon Material Test Plan

TOPICAL REPORT

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Task 1 Cooled Liner Coupon Development and Test

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DISCLAIMER

ABSTRACT

The test plan detailed in this topical report supports Task 1 of the project titled "Development of Technologies and Capabilities for Coal Energy Resources – Advanced Gasification Systems Development (AGSD)". The purpose of these tests is to verify that materials planned for use in an advanced gasifier pilot plant will withstand the environments in a commercial gasifier. Pratt & Whitney Rocketdyne (PWR) has developed and designed the cooled liner test assembly article that will be tested at CANMET Energy Technology Centre (CETC-O) in Ottawa, Ontario, Canada (CETC-O).

The Test Plan TP-00364 is duplicated in its entirety, with formatting changes to comply with the format required for this Topical Report. The table of contents has been modified to include the additional material required by this topical report. Test Request example and drawings of non-proprietary nature are also included as appendices.

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EXECUTIVE SUMMARY

This test plan document describes the technical work to be performed by CANMET and Rocketdyne at CETC-O. The technical details in this test plan represent the bulk of work done under Task 1 after the design phase, from April through November of 2005, and is presented as the body of this Topical Report. It comprises the detailed test methods to be used in the testing of cooled ceramic coupons at CETC-O. A summary of the Test Readiness Review meeting discussion is included in the section titled “Results and Discussion” and constituted formal approval of the test plan and hardware readiness for testing by Rocketdyne, CANMET and the Department of Energy.

The Test Request is the formal document to be used between Rocketdyne and CANMET to communicate and document daily changes to the gasifier instrumentation and operation, and an example is included in Appendix A.

The test assembly designs are included as Appendix B. The design was created from October of 2004 through April of 2005. All designs are signed and released by Rocketdyne engineers and the released version of these documents are kept in a locked electronic vault with signatures on file. The assembly of the hardware is as shown on these drawings.

The testing is to be accomplished by maintaining coolant flow through an outer jacket while the coal gasifier is being brought up to temperature, and the coolant flow is to be maintained during coal gasification to ensure slag deposition on the CMC liner.

Three materials are to be tested as the baseline plan. Backup materials are being kept on hand in case these materials fail, whether due to operational errors, manufacturing problems, or poor choice of material. However, it is the judgement of the designers and project engineers that the baseline materials are those with the highest chance of success. In case damage is caused not by a material problem but an operational error, one of the backup coupons is substantially the same as the baseline materials.

In addition to the basic question of material survivability, other issues to be investigated in the test include the transient heat load prior to reaching steady state with the slag layer, operating requirements prior to and during slag deposition, the basic morphology of the slag deposits, and how the slag sloughs off and is re-deposited during long term operation.

EXPERIMENTAL METHODS (TEST PLAN)

1.0 INTRODUCTION

This test plan supports Task 1 of the project titled "Development of Technologies and Capabilities for Coal Energy Resources – Advanced Gasification Systems Development (AGSD)". The purpose of these tests is to verify that materials planned for use in an advanced gasifier pilot plant will withstand the environments in a commercial gasifier.

Materials used for the hottest portion of the gasifier have been tested in static slag adhesion and corrosion oven tests at the US DOE Albany Research Center, but have not been subjected to the kinetic atmosphere of a gasifier reactor. The environment in this test will more closely simulate an actual gasifier: temperature, slagging environment, solids loading of the flow stream, hot gas velocity, cooling rates and heat flux of the test article will be similar to those expected in future phases of this project.

Although tests will not be performed over months of time, the tests planned will identify infant mortality issues, the efficacy of specific design details and material systems that will protect and isolate components from various environments in the gasifier.

2.0 OBJECTIVES

Test objectives are as follows:

- Demonstrate the concept of a gasifier arrangement with slag frozen onto a ceramic liner surrounded by a cooling jacket.
- Demonstrate that at least one of the materials selected for the ceramic liner will adhere to the frozen slag layer and prevent rapid deterioration of the liner.
- Develop flow and operational criteria for cooling of the CMC for optimal slag coating, including startup and shutdown procedures and limits.
- Gather data for thermal analysis and design for pilot plant and commercial gasifiers.
- Acquire data to project a useful life for these larger scale gasifiers.
- Evaluate at least three ceramic liner materials and coating processes.
- Evaluate a variety of corrosion resistant alloys and/or diffusion coatings.

- Establish the range of operation to prevent overcooling (plugging gasifier with slag) or undercooling (corrosion of the ceramic liner).

3.0 SCOPE

This test subjects a one foot section of a gasifier to the coal gasification environment to demonstrate materials and establish procedures for a future pilot plant. The test is intended to run in two phases: the first phase consists of two one day burn-in periods on two pairs (four material combinations) of similar liners to establish a slag layer on the CMC and provide a basis to move forward with one set for longer testing. Tests will last from 100-200 hours, depending on project budget available.
Any variations from this test plan will be supplied to the test conductor on or before the morning of the test day in the form of a Test Request (see section 8 Test Matrix) which is to be prepared and signed by a Rocketdyne Development Engineer.

4.0 TEST SUCCESS CRITERIA

Overall success of the CANMET tests will be established by the following criteria:

- CMC liners and cooling jacket remain intact at the end of the test campaign.
- Either no wear is seen on the liners and jacket, or the combination of materials leaves a clear choice with the best performance for pilot plant testing (based on least erosion on CMC, corrosion of surfaces on metal sample coupons – to be determined by a combination of visual/borescope inspection and destructive examination post-test).
- Tests provide useful data on startup and shutdown, particularly with respect to slag adhesion, material thermal shock, and slag surface buildup and morphology.
- Slag spalling data and/or metal corrosion data provide useful input to statistical analysis of CMC useful life.
- Provide data to select CMC materials.
- Provide data to select cooling jacket materials.
- Thermal control of cooling jacket methodology can be applied to pilot plant testing.

5.0 TEST HARDWARE

5.1 Test Assembly P/N 7R110019A1

The Test Unit consists of a 12" SCH 40 pipe with 300# class flanges. The cooling jacket is welded into this outer pressure shell and contains GN_2 coolant through channels to actively cool the CMC liner.
The syngas travels in from a 5" diameter flow passage into a reducing cone fabricated from castable refractory material, which channels the flow into a 1.875 inch diameter hole concentric with the same diameter CMC liner. The top ½" of this CMC liner extends above the cooling jacket, and in this relatively uncooled space are placed eight small material samples (see section 5.4).

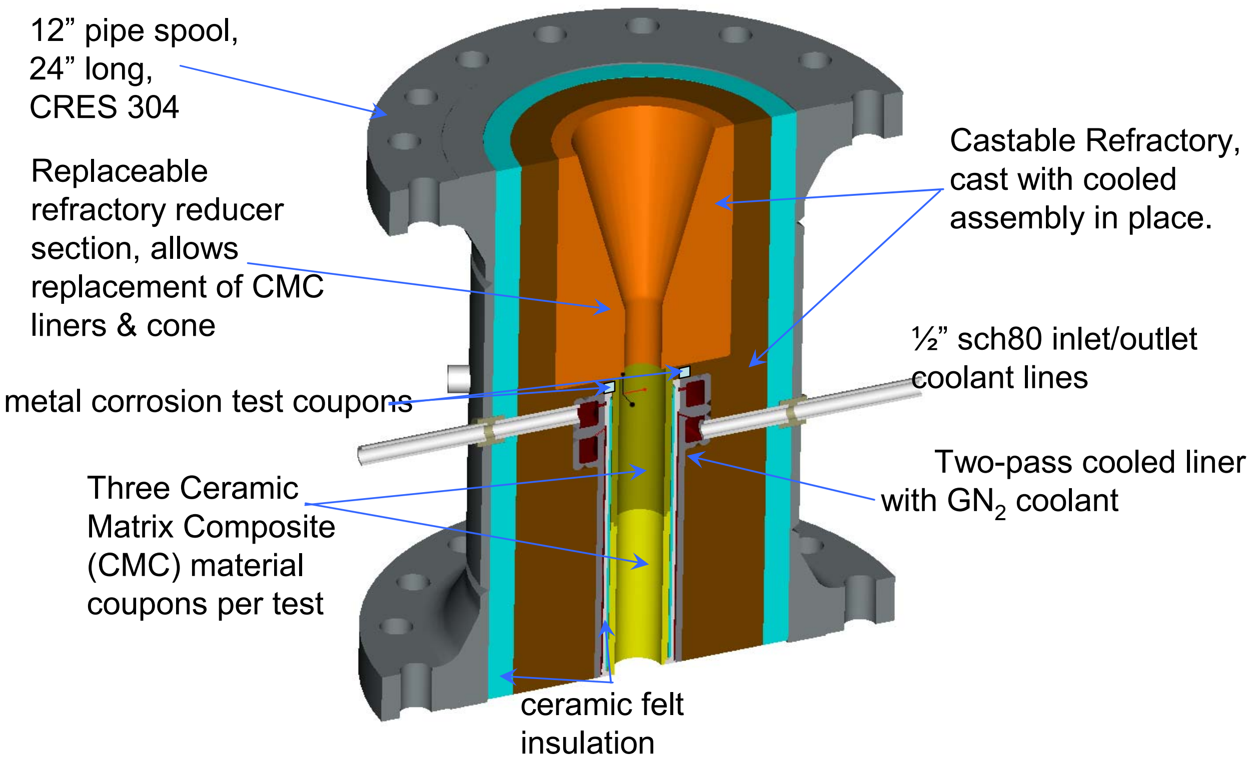


Figure 5.1 Test Assembly P/N 7R110019A1

5.2 CMC Liners P/N 7R110022

The Ceramic Matrix Composite liners are made in three pieces: an inlet (-3) and two outlets (-5). The rabbet joint between the liners is intended to simulate the rabbet joint that must be used to assemble a 15 foot long liner for a commercial plant and pilot plant. Four liners will be made, with different materials in the densification of the fiber reinforced composite. Holes in the first test inlet will allow thermocouples to measure syngas and slag temperatures in the reaction chamber and anchor thermal models. The fourth part will be reserved without final machining in case one of the three first parts fails in test. If the cause of the failure is the thermocouple holes, then the replacement part will be made without thermocouple holes.

Figure 5.2 differs from this description due to a change in the design. Originally two liners were to have been made to fill the gasifier test section, however machining accidents at the vendors making the parts resulted in shorter than required liners. The solution to recover from these errors is to make the liners 33% shorter and put three in place of two, covering the same overall length.

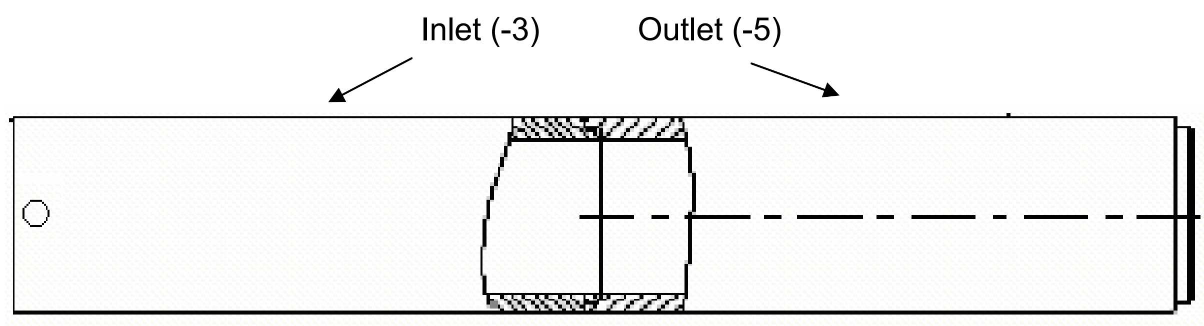


Figure 5.2 CMC Liners 7R110022-3 and -5

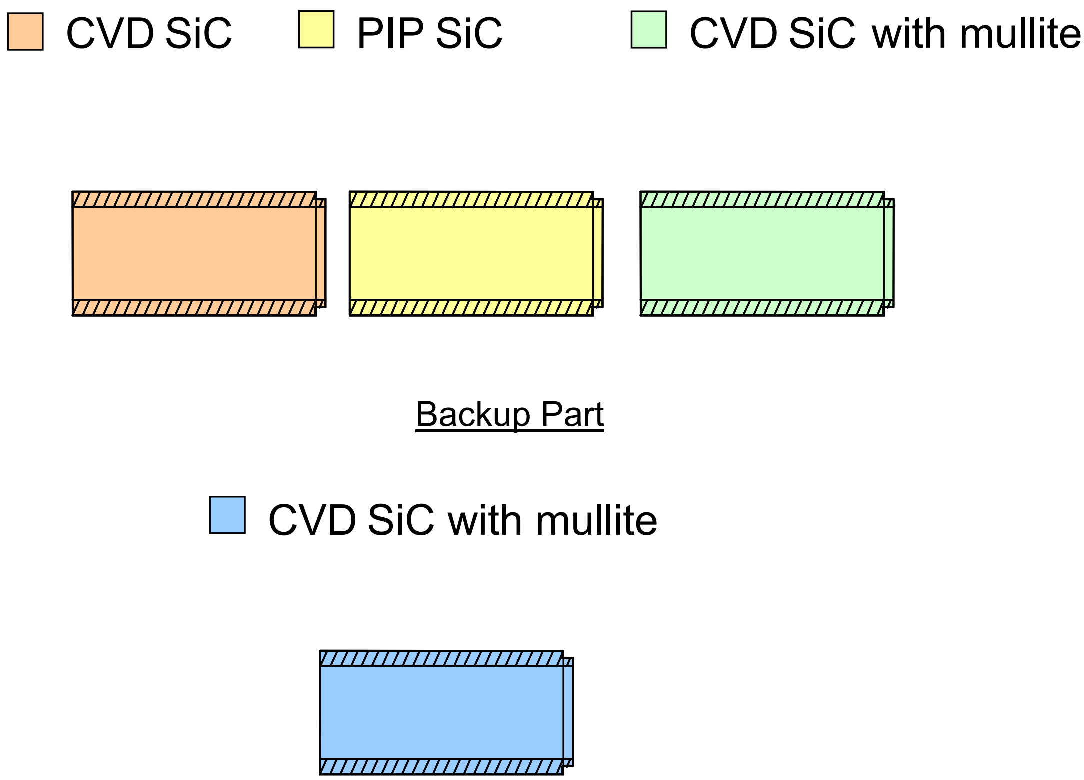


Figure 5.3 CMC Liner Fabrication Materials

5.3 Cooling Jacket P/N 7R110023

The cooling jacket, shown in Figure 5.3, is a two-pass heat exchanger using nitrogen to actively maintain a CMC temperature of approximately 815-982°C (1500-1800°F). The cooling control circuit will be configured to maintain this temperature at one location, which should produce an average metal temperature of 204°C (400°F) in the cooling jacket, controlled by the heat flux through the layers of syngas and ceramic felt (Fiberfrax®).

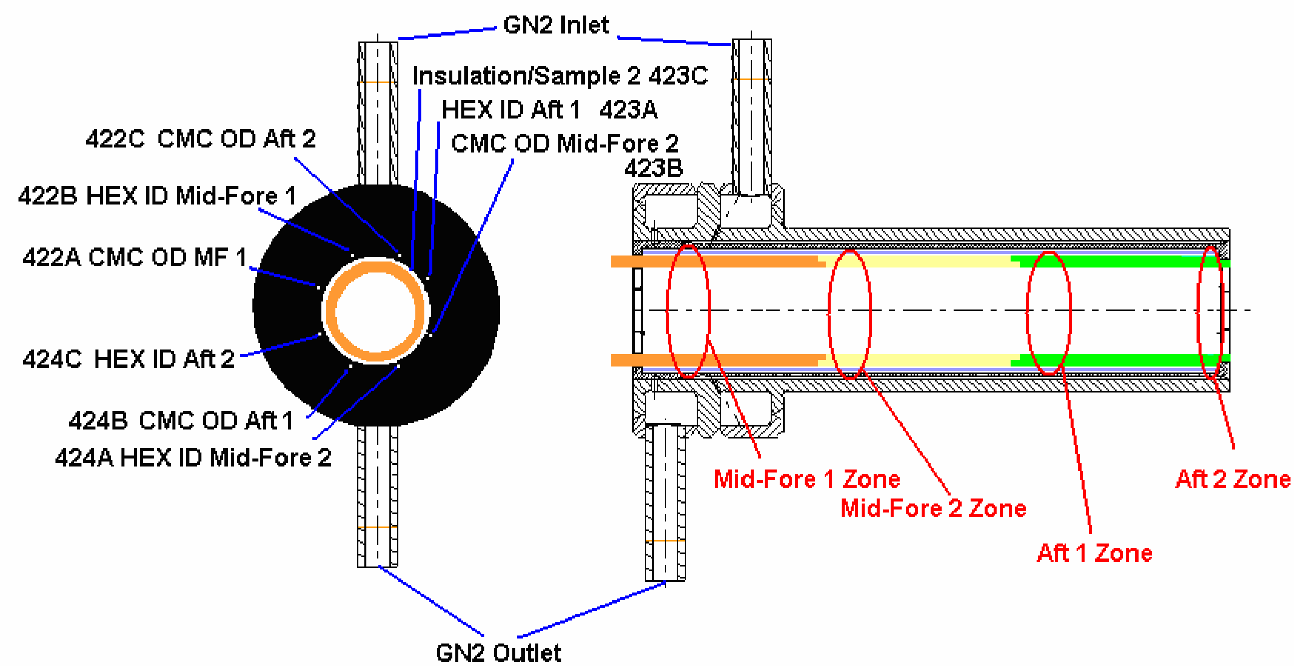


Figure 5.4 Cooling Jacket P/N 7R110023 cooled thermocouple locations

5.4 Material Samples and Miscellaneous Thermocouples

Upstream of the cooling jacket the CMC extends 12.5 mm (½ inch) to meet the refractory inlet reducing cone. In this zone several metal coupons will be placed to compare with each other as alternate materials to the aluminized stainless steel used for the Cooling Jacket. Several thermocouples will pass through this zone and record temperatures of samples, CMC, Slag and syngas. The locations of these thermocouples are shown in figures 5.5 and 5.6

Figure 5.5 Thermocouples Mounted on Coolant Outlet Side

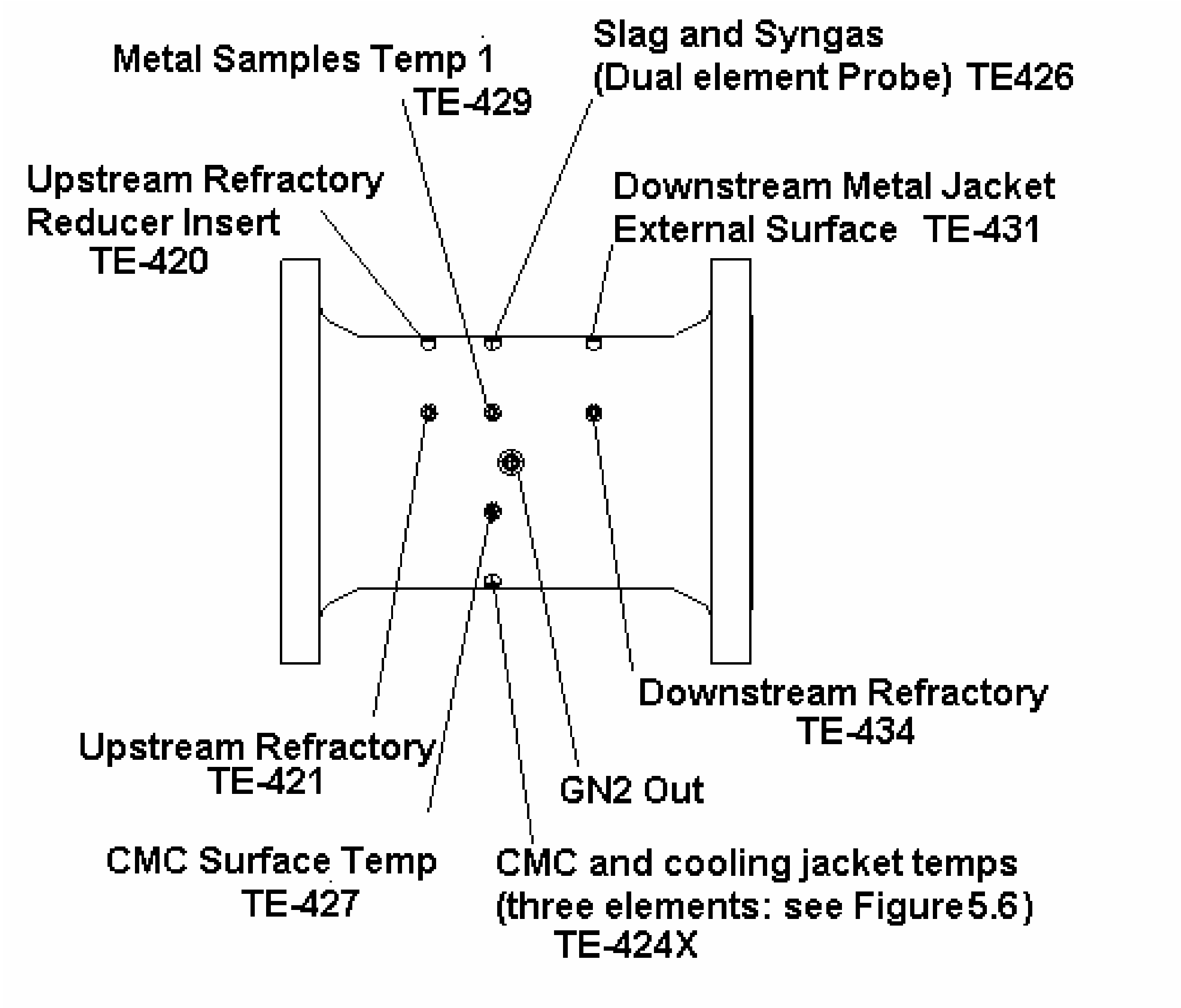
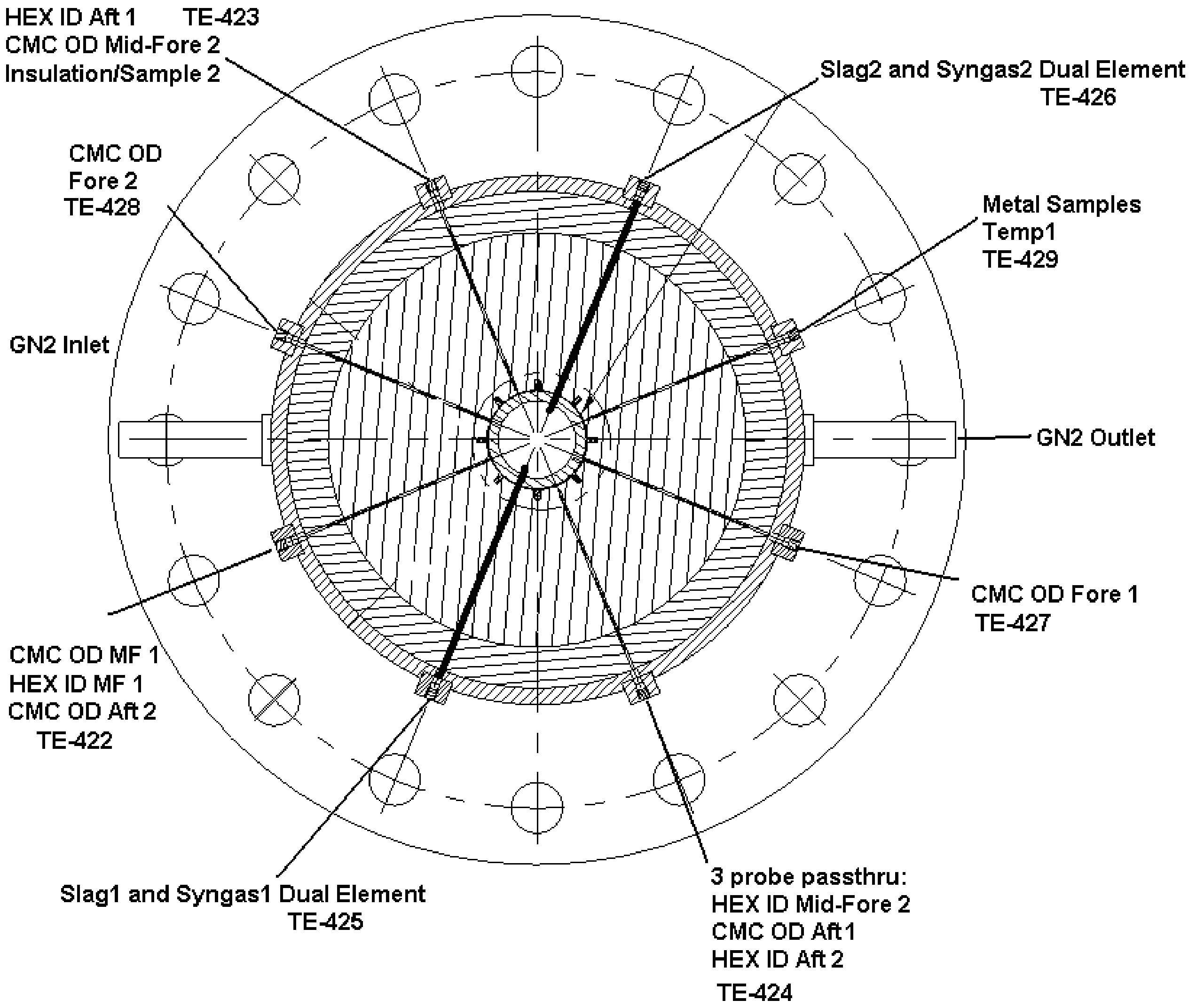


Figure 5.6 Thermocouple Bosses near the CMC Inlet Plane



5.5 Operating Pressures

The operating pressures of the hardware supplied by Rocketdyne are shown in Table 5.1. Proof pressure testing and leak checking of the assembly will be conducted before the hardware is shipped to Ottawa.

Several pressures and temperatures are listed for the cooling jacket in overheated conditions. This is to cover certain shutdown conditions in case the coolant flow is blocked or control is lost. If the cooling jacket becomes overheated it is not a serious concern unless it goes well beyond this P-T curve. This curve is based on maintaining a safety factor of 4 or more on Ultimate strength, but is approximate and conservative. The actual FS may be greater.

If coolant flow is compromised during shutdown and subsequent cool-down and temperature is not maintained in the cooling jacket, these pressure values should be used to manually decrease the coolant supply regulator if the part becomes overheated. If the cooling jacket temperature goes above 1200ºF, it would be best to set up a purge at a very low pressure to attempt to reduce risk of damage to the hardware.

Note also that this cooling jacket allowable pressure during normal operation would be the coolant gas pressure MINUS the syngas pressure, so in normal operation, the net coolant pressure on the joints will be almost zero.

Table 5.1 Operating and safety pressures of test hardware

	MAWP		Operating Temperature		Hydrostatic Pressure Test	
	kPa	(psia)	°C	(°F)	kPa	(psia)
Outer Shell	1827	(265)	538	(1,000)	3392	(492)
Cooling Jacket	2275	(330)	343	(650)	3619	(525)
Cooling Jacket (overheated condition)	2242	(325)	371	(700)		
	2209	(320)	399	(750)		
	2159	(313)	427	(800)		
	2126	(308)	454	(850)		
	1976	(287)	482	(900)		
	1644	(238)	510	(950)		
	1295	(188)	538	(1,000)		
	1046	(152)	566	(1,050)		
	847	(123)	593	(1,100)		
	664	(96)	621	(1,150)		
	531	(77)	649	(1,200)		

6.0 Test Facility Requirements

The test facility shall be capable of meeting the requirements for test operating conditions described in the following sections.

6.1 General

The gasifier shall have been tested at the inlet run conditions provided in this document prior to assembly with the Rocketdyne cooled liner test section. The desired gas temperatures and velocities shall have been verified and gas analysis performed to allow performance variation produced by the cooled liner and reduced residence time.

6.2 Gas Analysis

A mass spectrometer gas analysis will be provided to the Rocketdyne development engineer for every run.

6.3 Feed Systems

6.3.1 Coal Feed System

The CETC-Ottawa dry feed system will be used for these tests. If the slurry feed must be used due to unforeseen plant damage, a new test plan and test requests will be generated and a new TRR must be performed.

6.3.2 Other Feed Systems

The oxygen, steam and nitrogen flows will be controlled as described in the CANMET Gasifier Operations and Safety Manual. Flowrates and process gas temperatures are covered in the Test Matrix (Section 8).

6.3.3 Heat Exchanger Control System

Gaseous Nitrogen at 1.38 MPa (200 psig) ±10% shall be provided to the HEX inlet port. Flow control will monitor mass flow rate in and out (to verify there is no leakage of coolant into or out of the gasifier).

6.3.4 Decontamination

Post test the reactor must be cleared with a gaseous nitrogen purge to remove any steam or other potential condensates that may corrode the cooling jacket parts.
Development Engineering representatives may also need diamond cutting wheels to remove slag for disassembly and inspection operations.

7.0 INSTRUMENTATION

7.1 Instrumentation Lists

Table 7.1 and Table 7.2 show the instrumentation requirements in Metric and English engineering units respectively.

(Following two pages)

7.2 Alarms and Cutoff Conditions

Safety monitors are set at two levels: Alarms (Hi and Lo) are set for parameters which are at their maximum or minimum acceptable values, and indicate that action is to be taken to correct the situation; automatic cutoff is initiated when parameters reach their maximum (Hi-Hi) or minimum (Lo-Lo) for safe operation, or an unacceptable condition. The selection of the “acceptable” Hi or Lo alarm (as opposed to unsafe, or cutoff condition) is a judgment to be made based on knowledge of the system, hardware operating conditions and an understanding of the time it may take to go from the Alarm condition to the Cutoff condition.

Normally these parameters will be monitored by the data acquisition and control system on a 1 or 2 second control cycle, however during burn-in (first test of a new liner) the control and cutoff parameters should be on a 500 ms control cycle or better. In the event any redlines are exceeded with more than two consecutive sample points the control system shall advance to the normal safe shut down sequence.

An observer cutoff will be active. Special interest shall be given to the CMC and cooling jacket wall temperatures.

Note that the Hi and Lo parameter values in these tables are not the values for flow control of coolant, they are limits based on protecting the hardware for damage. Optimal coolant control ranges will be determined prior to test day and will be communicated in the Test Request (see section 8.3).

Table 7.1 Instrumentation list in Metric units

PARAMETER	No Test	SENSOR (or alternate)	NOMINAL MAG.	UNITS	RANGE		Measurement Uncertainty @ Nom. Temp.	Closed Loop Control	Alarms				P&ID
					min	max			Lo-Lo	Lo	Hi	Hi-Hi	
Gasifier Spool Jacket													
Spool OD Fore	N	Type K	100	°C	-200	1250	± 0.8°C				500	550	
Reducer OD Fore	N	Type K	250	°C	-200	1250	± 1.9°C						TE-420
HEX OD Aft		Type K	180	°C	-200	1250	± 1.4°C						TE-431
Spool Insulation Fore		Type K	300	°C	-200	1250	± 2.3°C						TE-421
Spool Insulation Aft		Type K	300	°C	-200	1250	± 2.3°C						TE-434
Heat Exchanger/Liner													
CMC OD Mid-Fore 1		Type N	935	°C	-270	1300	± 7°C		760	787	982	1093	TE-422A
HEX ID Mid-Fore 1	N*	Type N	190	°C	-200	1300	± 1.4°C	Alt3	120	176	315	980	TE-422B
CMC OD Aft 2		Type N	840	°C	-200	1300	± 6.3°C		760	787	982	1093	TE-422C
HEX ID Aft 1	N*	Type N	220	°C	-200	1300	± 1.7°C	Alt1	120	176	315	980	TE423A
CMC OD Mid-Fore 2		Type N	870	°C	-270	1300	± 6.5°C		760	787	982	1093	TE423B
HEX ID Mid-Fore 2	N*	Type N	190	°C	-200	1300	± 1.4°C	400	120	176	315	980	TE-424A
CMC OD Aft 1		Type N	840	°C	-200	1300	± 6.3°C		760	787	982	1093	TE-424B
HEX ID Aft 2	N*	Type N	220	°C	-200	1300	± 1.7°C	Alt2	120	176	315	980	TE-424C
Sample Temp 1	N**	Type N	220	°C	-200	1300	± 1.7°C						TE-423C
Sample Temp 2	N**	Type K	220	°C	-200	1250	± 1.7°C						TE-429
CMC OD Fore 1	N**	Type K	870	°C	-200	1250	± 6.5°C						TE-427
CMC OD Fore 2	N**	Type K	870	°C	-200	1250	± 6.5°C						TE-428
Slag Fore 1		Type B	1127	°C	300	1760	± 8.5°C						TE-425B
Syngas Fore 1		Type B	1128	°C	300	1760	± 8.5°C						TE-425A
Slag Fore 2		Type B	1129	°C	300	1760	± 8.5°C						TE-426B
Syngas Fore 2		Type B	1130	°C	300	1760	± 8.5°C						TE-426A

* At least one of four. See test request for details.

** At least one of four. See test request for details.

Table 7.2 Instrumentation list in English Units

PARAMETER	No Test	SENSOR (or alternate)	NOMINAL MAG.	UNITS	RANGE		Measurement Uncertainty @ Nom. Temp.	Closed Loop Control	Alarms				P&ID
					min	max			Lo-Lo	Lo	Hi	Hi-Hi	
Gasifier Spool Jacket													
Spool OD Fore	N	Type K	210	°F	-330	2300	± 1.6°F				930	1020	
Reducer OD Fore	N	Type K	480	°F	-330	2300	± 3.6°F						TE-420
HEX OD Aft		Type K	360	°F	-330	2300	± 2.7°F						TE-431
Spool Insulation Fore		Type K	570	°F	-330	2300	± 4.3°F						TE-421
Spool Insulation Aft		Type K	570	°F	-330	2300	± 4.3°F						TE-434
Heat Exchanger/Liner													
CMC OD Mid-Fore 1		Type N	1720	°F	-450	2400	± 12.9°F	0	1400	1450	1800	2000	TE-422A
HEX ID Mid-Fore 1	N*	Type N	370	°F	-330	2400	± 2.8°F	Alt3	250	350	600	1800	TE-422B
CMC OD Aft 2		Type N	1540	°F	-330	2400	± 11.6°F		1400	1450	1800	2000	TE-422C
HEX ID Aft 1	N*	Type N	430	°F	-330	2400	± 3.2°F	Alt1	250	350	600	1800	TE423A
CMC OD Mid-Fore 2		Type N	1600	°F	-450	2400	± 12°F		1400	1450	1800	2000	TE423B
HEX ID Mid-Fore 2	N*	Type N	370	°F	-330	2400	± 2.8°F		250	350	600	1800	TE-424A
CMC OD Aft 1		Type N	1540	°F	-330	2400	± 11.6°F		1400	1450	1800	2000	TE-424B
HEX ID Aft 2	N*	Type N	430	°F	-330	2400	± 3.2°F	Alt2	250	350	600	1800	TE-424C
Sample Temp 1	N**	Type N	430	°F	-330	2400	± 3.2°F						TE-423C
Sample Temp 2	N**	Type K	430	°F	-330	2300	± 3.2°F						TE-429
CMC OD Fore 1	N**	Type K	1600	°F	-330	2300	± 12°F						TE-427
CMC OD Fore 2	N**	Type K	1600	°F	-330	2300	± 12°F						TE-428
Slag Fore 1		Type B	2060	°F	570	3200	± 15.5°F						TE-425B
Syngas Fore 1		Type B	2060	°F	570	3200	± 15.5°F						TE-425A
Slag Fore 2		Type B	2060	°F	570	3200	± 15.5°F						TE-426B
Syngas Fore 2		Type B	2070	°F	570	3200	± 15.5°F						TE-426A

* At least one of four. See test request for details.

** At least one of four. See test request for details.

7.3 Data Reduction

The facility shall have a data archival and post-processing capability to allow analysis on a laptop computer following each test for quick assessment of test results. All acquired data shall be transferred onto PC-compatible media for transmittal to Rocketdyne following each test series.

Some may be processed in real time for quicklook analysis, such as total heat loss into the coolant gas, which should be relatively straightforward. Other possibilities include syngas temperature based on probes which have a high delta-T and syngas exit temperature, however these are not critical and spot checks can be done by hand if processing overhead time or programming time is too expensive to justify.

Real time calculated parameters will be discussed and selected as a team prior to test day one and will be covered in the Test Request.

8.0 Testing

8.1 Test Matrix

The planned test matrix is shown in Table 8.1. Each day of testing will constitute a test which will usually be performed at one syngas temperature and velocity and (except for first day burn-in) operated for a full day unless a redline condition is violated. The specific order of tests has been selected to achieve higher priority objectives first and remaining objectives later in the test campaign.

Table 8.1 Daily Test Matrix

Day	Test Objective	Syngas (inlet of CMC)				
		Temp		Velocity (min)		Duration
		°C	(°F)	m/s	(ft/sec)	hours
1	Burn in liners	1450	(2,642)	6.1	(20)	1
2	Visual exam	N/A				
3	Life test	1450	(2,642)	6.1	(20)	8
4	Life test	1450	(2,642)	6.1	(20)	8
5	Life test	1450	(2,642)	6.1	(20)	8
6	Life test	1450	(2,642)	6.1	(20)	8
7	Life test	1450	(2,642)	6.1	(20)	8
8	Life test	1450	(2,642)	6.1	(20)	8
9	Life test	1450	(2,642)	6.1	(20)	8
10	Life test	1450	(2,642)	6.1	(20)	8
11	Life test	1450	(2,642)	6.1	(20)	8
12	Life test	1450	(2,642)	6.1	(20)	8
13	Life test	1450	(2,642)	6.1	(20)	8
14	Life test	1450	(2,642)	6.1	(20)	8
…	Additional tests if funds available	1450	(2,642)	6.1	(20)	8

The first test of a new CMC liner (burn-in) will be only short duration (15-60 minutes) followed by a visual inspection by borescope provided by Rocketdyne to establish that a protective coating of slag has been uniformly deposited on the inner surface of the test spool and to establish that there aren't any obvious holes in the CMC.

Damage to the CMC is not necessarily grounds to stop the test, however extreme losses of material will likely cause a delay while photographs can be sent back to Canoga Park and examined by Rocketdyne materials engineers.

The first morning after a full day of testing the coupons shall also be inspected by borescope. If this inspection can be made without shortening the test time, it should be repeated every day. If on the other hand the tests are delayed significantly by this inspection, the borescope inspections should be reduced, and should only be done if the thermocouples show changes in temperature of the test article at steady state conditions.

If slag deposition is not uniform or shows signs of being too low in temperature one of the following may occur:

1. Re-test with increased reactor temperature
2. Re-test with lower nitrogen coolant flowrate
3. Re-test with calcium or other fluxing agents added to the coal
4. Replace liner and test the other liner with one or all of the above conditions

Any anomaly that produces plugging or obvious damage to the CMC or refractory that is observable by thermocouple over-temperatures or destruction will cause a test stand-down for at least a day while one or more of the following can take place:

1. Borescope inspection
2. Replace the refractory reducing cone
3. Free the plugged or damaged CMC liner or replace it
4. Replace the damaged thermocouple or make the decision to run without it

A logic chart is shown in Table 8.2 to provide guidance in the field.

8.2 Flow Controls

The various feed systems shall be capable of maintaining the required syngas velocity and temperature at the test spool inlet:

Nominal: 1425 °C (2597 °F); 10.66 m/s (35 ft/s)
Low: 1400 °C (2552 °F); 9.14 m/s (30 ft/s)
High: 1450 °C (2642 °F); 12.19 m/s (40 ft/s)

On any given day, the coal flowrate should be fixed as listed in the Test Request, and the steam and oxygen flowrates adjusted to maintain the temperature range.

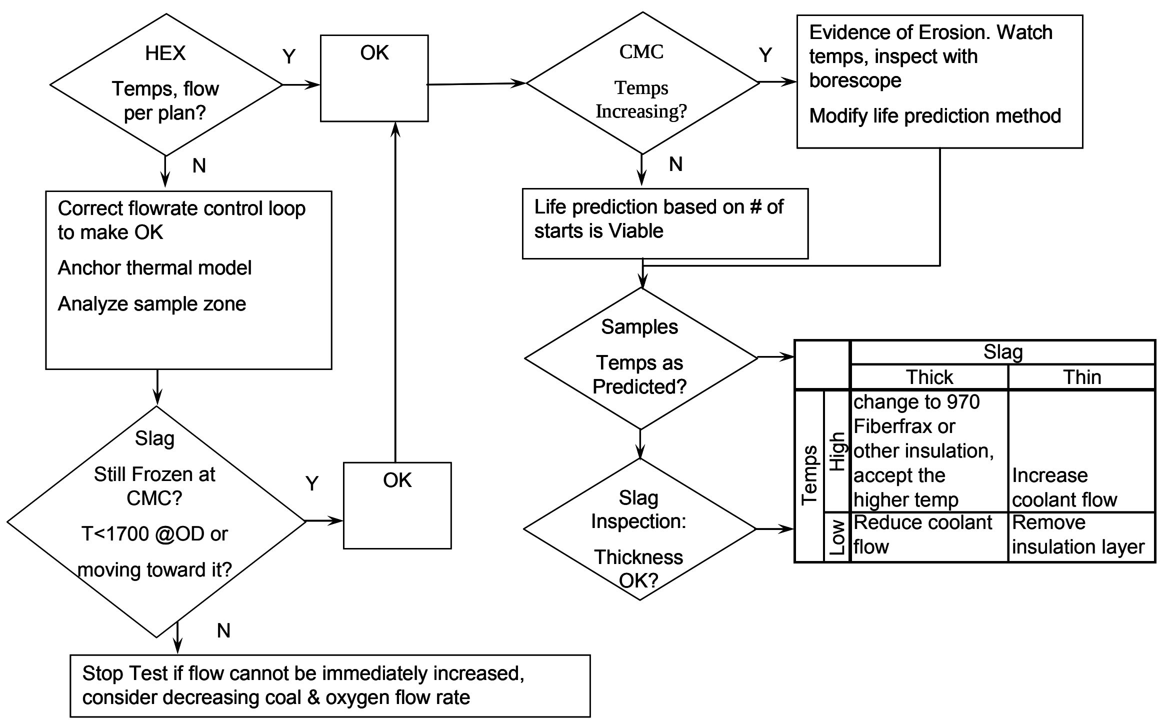
GN2 coolant flow shall be maintained on a temperature control algorithm during "burn-in" (first test of a new liner). This may be control of a particular thermocouple, however it is desirable to control based on four thermocouples (choosing the maximum of four in order to avoid controlling a damaged or de-bonded thermocouple). Thereafter, subsequent tests may be performed with a flow rate control rather than temperature control, in order to examine the variability of temperature with coolant flow.

Actual control parameters (temperature or flowrate upper and lower limits) will be identified in the Test Request for each day of test (see next section).

8.3 Test Request

The actual tests to be run and the order of testing within the series will be specified in the Test Request and will be selected from the detailed test series matrix in Table 8.1, with instrumentation and control changes in accordance with the logic shown below:

Figure 8.1 Test Decision Logic Chart



The Test Request will also include any changes to the Hi and Lo cutoff parameter limits. An example Test Request is shown in Appendix A.

9.0 Data Acquisition and Reduction

9.1 Data Reduction/Post Test Analysis Requirements

Real time test data reduction will be accomplished with a direct connection from the control computer to an excel spreadsheet on a satellite machine. If the thermal model indicates that the conductivities are changing, this should at the very least prompt a borescope inspection on the next day. The decision matrix above shows what to do in real time in test.

9.2 Quick Look Digital Data Requirements Between Tests

If the test data is properly being transferred to the satellite computer, as long as this data is supplied to the development engineer the only other requirement is that the syngas analysis results are transmitted to Rocketdyne Canoga Park for anchoring the combustion model of the process.

9.3 Video/Photographic

9.3.1 Video

No video coverage is expected.

9.3.2 Photographic

Photos of the as-installed test article shall be taken of the seals, thermocouples and facility installation. Special care must be taken by the cognizant engineer to document the metal coupon samples and small thermocouples in the CMC OD space to ensure the instrumentation is properly labeled in test.

Photos of any abnormal conditions inside the gasifier affecting operation of the CMC cooled liner, for example, excessive slag layering or blockage shall be taken.

Any borescope inspections must be documented with saved images, especially documentation of spalled surfaces and other damage to the test article.

9.4 Pre- and Post-Test Inspections

Pressure and leak tests must be done before testing as part of CANMET's safety procedure. Post test inspections include a complete disassembly of the entire test article and destructive evaluation of the CMC coupons, and non-destructive testing of the metal coupons (mass) followed by destructive evaluation if called for by significant mass loss in a sample of interest.

10.0 TEST READINESS REVIEW

Approximately 8 to 12 weeks before the scheduled test date, a Technical Interface Meeting (TIM) will be conducted with Rocketdyne and CANMET. The purpose of the TIM will be to review the final test plan, to status equipment and facility test preparation and to obtain concurrence to proceed with any changes to detailed test procedures, control systems, etc.

A test readiness review (TRR) shall be conducted with the test facility approximately 4-8 weeks prior to the first test. At this time the test procedures and the test request should be reviewed and approved by all involved organizations. All action items identified in the TIM should be addressed and closed.

Prior to each day of testing a test request review shall be conducted by the joint Rocketdyne-CANMET test group to ensure the tests are addressing program issues, that security and safety have been adequately considered and that all participating agencies are ready to test.

THIS ENDS THE TEST PLAN

TASK 1 TOPICAL REPORT CONTINUES ON THE NEXT PAGE

RESULTS AND DISCUSSION

The hardware design and experimental method was reviewed by Rocketdyne design review board in March of 2005. Some minor changes to hardware were recommended and implemented prior to drawing release, however there were no substantial changes to the test methodology proposed. The hardware was built according to the designs shown in Appendix B.

The test plan was reviewed internally by Rocketdyne and a test readiness review was held with CANMET and Rocketdyne personnel. The review identified several actions to be taken prior to the start of testing. These actions are described below. All actions are complete at the time of this writing.

- Correct the range of Type B thermocouples to 300-1760°C
- Correct the “No Test” parameter designation for thermocouples under CMC to reflect “at least one of four” rather than all eight as implied by Table 7.1 (Clarified also in the test request.)
- Test Request should include Oxygen and Steam temperatures
- Send a copy of the safety procedure and FMECA analysis to quality for review.
- Identify the natural gas flowrate for warmup prior to the first test.

Since this topical report consists entirely of test methods, and not test results, there can be no discussion of results. Test results will be discussed in the Task 1 CMC Liner Test Results Topical Report to be submitted at the conclusion of the test program.

CONCLUSION

Rocketdyne and CANMET have agreed the system is ready for testing. The results of the testing will be reported in the first quarter of 2006 at the conclusion of the test program. This test plan represents only the test methodology and logic for gasifier cooled liner operation. This test approach represents a low cost low risk method of determining the readiness of this technology, as it is an actual scale model of a gasifier pilot plant with cooled liner, and the test conditions are reproducing as closely as possible the actual conditions in a larger gasifier.

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ACRONYMS AND ABBREVIATIONS

A Amperes
AGSD Advanced Gasification Systems Development
ANSI American National Standards Institute
ASME American Society of Mechanical Engineers

B&PV Boiler and Pressure Vessel Code controlled by ASME

°C degrees Centigrade/Celcius
CANMET Canada Materials and Energy Technologies branch of NRCan
CETC-O CANMET Energy Technology Centre - Ottawa
CMC Ceramic Matrix Composite
CS Carbonaceous Solids
CVD Chemical Vapor Deposition

DDACS Digital Data Acquisition and Control System
DI de-ionized
DOE Department of Energy

°F degrees Fahrenheit
FS Factors of Safety
ft feet

g grams
G gravitational force constant multiple
GN_2 Gaseous Nitrogen
GND Ground

HEX Heat Exchanger
HIP High Interface Pressure braze
Hz Hertz

KPa kiloPascal

lbf Pounds Force
lbm Pounds Mass

MHz Megahertz
MPa Mega Pascal
ms milliseconds

N Newton
NIST National Institute of Standards and Technology (Gaithersburg, MD)

NPT National Pipe Thread standard

NRCan Natural Resources, Canada
P/N Part Number
PIP Polymer Infiltration and Pyrolysis
psia Pounds per Square Inch Absolute
psid Pounds per Square Inch Difference
psig Pounds per Square Inch Gage

RD Boeing/Rocketdyne Propulsion and Power

SCH Schedule: piping standard
scfm Standard Cubic Foot per Minute
scm Standard Cubic Meters

TC Thermocouple
TRR Test Readiness Review

VCR Video Cassette Recorder

APPENDIX A: TEST REQUEST EXAMPLE

Cooled CMC Lined Coal Gasifier	**7R110019**	**Test Number:**	**2**
		Test Date:	**01 December, 2005**
Test Stand:	**CANMET Energy Technology Centre, Ottawa, Natural Resources, Canada**		
Rocketdyne Test Engineer:	Mark Fitzsimmons, Combustion Devices Development	**Signature**	
CETCO Test Engineer:	Robin Hughes	**Signature**	

Test Setup Parameters			**ACTUALS Time Slice**
Test Duration After Heat Up: At full coal flowrate	30	minutes	
Reactor Pressure PT-421	800	kPa	
Coal Flowrate FI-52	20	kg/hour	
Oxygen Flowrate FT-21A	21	kg/hour	
Steam Flowrate FI-305	8	kg/hour	
Oxygen Temperature TE-21A3	0	°C	
Steam Temperature TE-300	0	°C	
Target Syngas Temp TE-425A	1400-1450	°C	
Heat up N.G. flowrate	65	SCFH	
Heat up air flowrate	35	SCFM	
Excess Oxygen flowrate AT-100Q	3-4	Flue Gas vol%	

Coolant Setup Parameters				**ACTUALS Time Slice**
	GN2 Coolant Pressure PT-250	1380	kPa	
	Coolant Control Set Points			
(filled box below indicates control method to use at start of test)				
▼				
■	**Flowrate control:**	36	kg/hour	
□	**Temperature control:**	204.4	°C	
	Using Parameter:	**TE424A**		
	or, if damaged:	TE423A	Alternate #1	
		TE424C	Alternate #2	
		TE422B	Alternate #3	
	Target Slag Temp TE-425A,B, 426B	900-950	°C	
	After test, cool until parameter	**TE420**		
	reaches	200	°C	
	during cool down			

Test Objectives:

- Get further data on thermal coefficients with GN2 at 200 psi
- Calibrate thermal conductivity of CMC to anchor thermal model, validate insulation analysis.
- Prove that no false redlines will be activated with existing settings, or find the correct alarm set points.
- Apply slag layer to inside of CMC tube.

Success Criteria

- Complete heat up and cool down while coolant loop is running.
- Collect data on thermal conductivity through CMC
- Anchor thermal model to allow fine tuning of coolant flows, control setpoints and alarms
- Apply slag layer.

Post Test Checkouts

- Borescope inspection

A. Special Instructions

Heat up and coal combustion/gasification test. Coolant must run the entire time. Discontinue natural gas as soon as possible after coal ignition. Note that HEX ID Low Alarms should not be set until after heat up cycle is underway.

B. Purge Requirements

Purge with GN2 as required after combustion process is complete. Cycle purge on for one minute, off for one minute. Repeat only if necessary. When CMC temps continue to go down and steel stays below 400F, stop purging.

C. Changes From Prior Test:

None

D. Open Items:

Cooled CMC Lined Coal Gasifier **7R110019** **Test Number:** **2**

Test Date: **01 December, 2005**

Test Stand: **CANMET Energy Technology Centre, Ottawa, Natural Resources, Canada**

Rocketdyne Test Engineer: Mark Fitzsimmons, Combustion Devices Development

CETCO Test Engineer: Robin Hughes

Gasifier Alarm Setpoints	**LO-LO**	**LO**	**HI**	**HI-HI**	**UNITS**	**PID**	**Purpose**
Spool OD Fore			500	538	°C	TE-433	Avoid thermal limit of shell
CMC OD Mid-Fore 1	760	787	982	1093	°C	TE-422A	Avoid solidus/liquidus at high temp. Avoid poor bond at low temp
HEX ID Mid-Fore 1	120	176	315	980	°C	TE-422B	Avoid braze and weld damage
CMC OD Aft 1	760	787	982	1093	°C	TE-424B	Avoid solidus/liquidus at high temp. Avoid poor bond at low temp
HEX ID Aft 1	120	176	315	980	°C	TE423A	Avoid braze and weld damage
CMC OD Mid-Fore 2	760	787	982	1093	°C	TE423B	Avoid solidus/liquidus at high temp. Avoid poor bond at low temp
HEX ID Mid-Fore 2	120	176	315	980	°C	TE-424A	Avoid braze and weld damage
CMC OD Aft 2	760	787	982	1093	°C	TE-422C	Avoid solidus/liquidus at high temp. Avoid poor bond at low temp
HEX ID Aft 2	120	176	315	980	°C	TE-424C	Avoid braze and weld damage

"No Test" Parameters			**Reason**
Spool OD Fore	TE-3xx		Detect overtemperature for safe operating condition. Redline.
Reducer OD Fore	TE-420		Detect complete erosion of Reducer.
HEX ID Mid-Fore 1	TE-422B	*	Closed loop control parameter.
HEX ID Aft 1	TE423A	*	
HEX ID Mid-Fore 2	TE-424A	*	
HEX ID Aft 2	TE-424C	*	
Sample Temp 1	TE-423C	**	Detect overtemperature for CMC damage or early failure or inadequate cooling
CMC OD Fore 1	TE-427	**	
CMC OD Fore 2	TE-428	**	
Sample Temp 2	TE-429	**	

* At least one of these four temperatures must be working to operate the gasifier according to the proposed test scheme.
If one of these four is not available, the thermal analysis must be revisited to use a different parameter.
Alternate: Flow may be controlled with TE431 if prior tests show this thermocouple is reading the HEX temperature accurately.

** At least one of these four temperatures must be working as a diagnostic tool in case there is gross leakage behind the CMC or to detect early failure of the CMC leading edge, or to detect inadequate cooling at the inlet end.
If one of these four is not available, replace the thermocouple so that it is working.

APPENDIX B: TEST ASSEMBLY DRAWINGS

NOTE: Drawings which include proprietary data are not included in this "unlimited distrubution" report submittal.

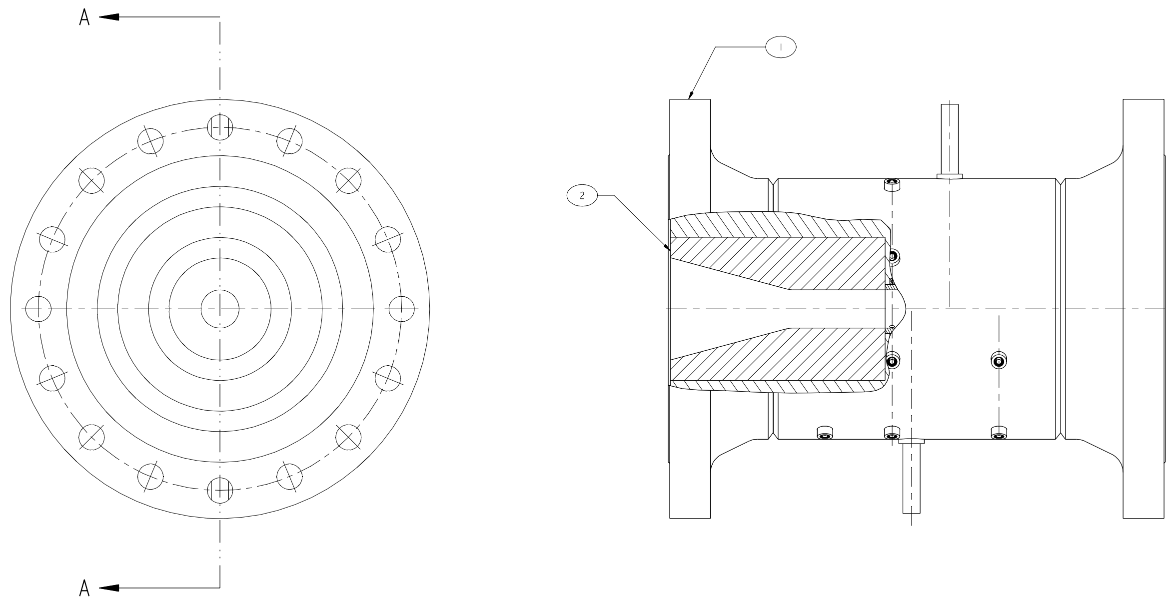
Indentured parts list:

Drawing Numbers	Quantity	Proprietary Data?	Title
7R110019	1	N	PLAIN LINER TEST ASSY
7R110029-7	1	N	MOLDED REPLACEABLE CONE
7R110020	1	N	CASTING PLAIN LINER ASSY OF
7R110021-1	1	N	PLAIN LINER WELDED ASSY OF
7R110021-3	1	N	FILLER, CASTABLE CERAMIC
7R110021-5	2	N	1/2" SCH40S Pipe
7R110021-7	1	N	Insulation, Liner
7R110021-9	1	N	Insulation, Inner
7R110022-3	1	Y	Liner, CMC, Inlet
7R110022-5	2	Y	Liner, CMC, Outlet
7R110023D1	1	Y	Plain Liner Machined
7R110024	1	Y	Plain Liner Braze Assy of
7R110025-1	1	Y	Jacket, Liner, Gasifier Assy of
7R110025-3	1	Y	Jacket, liner
7R110025-7	2	Y	closeout, Manifold
7R110026	1	Y	Liner, Slotted, Advanced Cooled, Gasifier
7R110030-1	1	N	Housing Welded Assy,Heat Exchanger, Gasifier
7R110030-3	1	N	Housing, 12" Pipe
Tooling Only:			
7R110027-1		Y	Sample, Braze, Cooled Coupon Assy of
7R110027-3		Y	Channel, Channel, Cooled Coupon
7R110027-5		Y	Jacket, Braze Sample, Cooled Coupon
7R110027-7		Y	Tube, Braze Sample, Cooled Coupon
7R110028-1		N	Tooling, Filler, Castable, Ceramic, assy
7R110028-3		N	Flange, Base, 300LBS
7R110028-5		N	Flange, Blind, 300LBS
7R110028-7		N	Mold, Cone
7R110028-9		N	Mold, 1.875" Hole
7R110029-1		N	Mold, Castable Ceramic, Replacement Cone, Gasifier
7R110029-3		N	Mold, Cone, Outside
7R110029-5		N	Mold, Cone, Inside

REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED

1. CLEAN SHALL BE PERFORMED TO REMOVE OIL, SCALE, RUST, AND OTHER GENERAL CONTANINATION FROM HARDWARE DURING AND AFTER MANUFATURING PROCESS.
2. TAG IDENTIFY PER RF0004-044 TYPE XI. DO NOT SERIALIZE.



SECTION A-A

QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	SH	ZONE
1	2	7R110029-7	02602	CONE REPLACEABLE		
1	1	7R110020-1	02602	CASTING PLAIN LINER ASSYOF		
-	-	7R110019A1	02602	PLAIN LINER TEST ASSY	--	--

PARTS LIST

DESIGNED BY H. HUYNH

DWG NO. 7R110019A1 SH 1

PDM MODEL REV 1.6
PDM DRAWING REV 1.7

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125√ MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES : ±0°30'
  - DECIMALS : .XX ±.03
    .XXX ±.010

DO NOT SCALE PRINT

CONTRACT DE-FC26-04NT42237
CREATION DATE 05-05-04
RELEASE STAMP

RELEASED DOCUMENT

APPROVALS ON RECORD

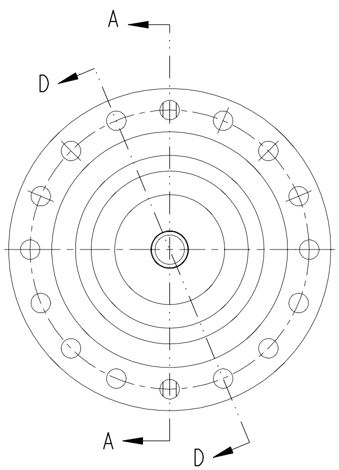
BOEING Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

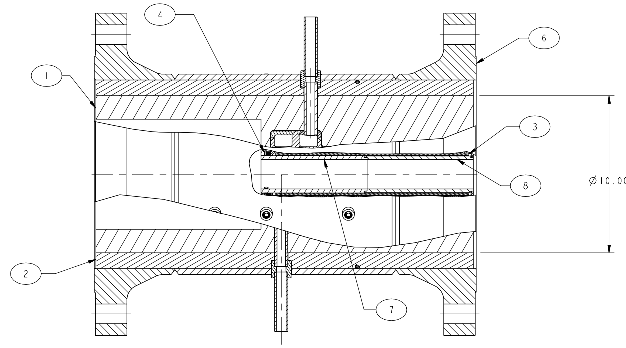
PLAIN LINER, TEST ASSEMBLY

SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110019A1

SCALE 1/2 SHEET 1 of 1

FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)





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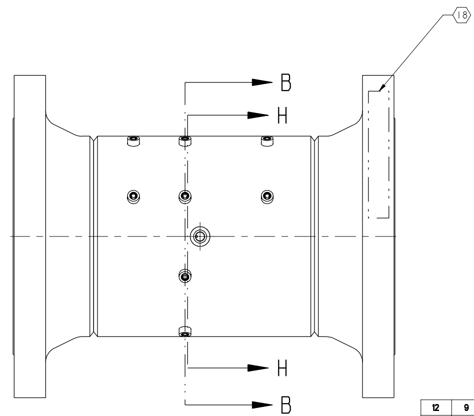
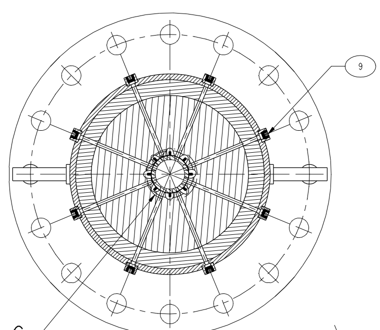
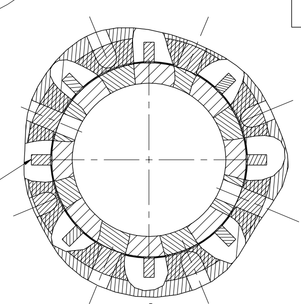




SEE DETAIL G

SECTION B-B
H-H



DETAIL G
SCALE 2/1

REVISIONS	ALL SHEETS SAME REV		
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED

1. USE CERAMIC FILLER TOOLING 7R110028 TO FILL CASTABLE CERAMIC.
2. INSTALL AND TEST TWO TYPE K THERMOCOUPLES PRIOR TO INSTALLING FIBERFRAX (2).
3. INSTALL AND TEST TWO TYPE K THERMOCOUPLES BETWEEN FIBERFRAX (2) AND CMC LINERS (7) AND (8).
4. INSTALL DUMMY TYPE S THERMOCOUPLE PROBES COATED WITH OIL PRIOR TO POURING REFRACTORY.
5. USE MOTOR OIL OR PETRLEUM JELLY ON MOLD PARTS FOR RELEASE CAST REFRACTORY PER MANUFACTURE'S MSDS INSTRUCTION AND SHEA LETTER HM00813 WHEN HANDLING POWDER AND WET MIX. MIX OUTSIDE ONLY WITH SAFE PERIMETER. VIBRATE FOR ONE TO FIVE MINUTES TO SETTLE MIX. LET PARTS SIT AND DRY FOR ONE DAY MINIMUM BEFORE REMOVING MOLD.
6. AFTER CASTABLE REFRACTORY IS POURED AND MOLD ARE TAKEN APART. BAKE TO THE FOLLOWING CYCLES:
   FROM AMBIENT TO 158°F AT 77°F/HR
   HOLD FOR 5 HRS AT 158°F
   FROM 158°F TO 248°F AT 59°/HR
   HOLD FOR 12 HRS AT 247°F
   FROM 248°F NTO 572°F AT 77°F/HR
   HOLD FOR 4 HRS AT 572°F
   FROM 572°F TO 1112°F AT 77°F/HR
   HOLD FOR 4 HRS AT 1112°F
   SLOW COOL.
7. USE CERAMIC PER ENGINEERING INSTRUCTION.
8. DEEP ELECTROCHEMICAL ETCH IDENTIFY PER RF0004-044 TYPE IV.
9. PACKAGE PROTECTION PER RA0116-094, METHOD P-1.

QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION NOTES, SUPPLIERS	SH	ZONE
12	9	THERMOCOUPLE_HX	02602	THERMOCOUPLE	VARIOUS	TBD		
1	8	7R110022-5	02602	LINER, CMC, OUTLET				
1	7	7R110022-3	02602	LINER, CMC, INLET				
1	6	7R110021-1	02602	PLAIN LINER WELDED ASSY OF	TBD	TBD		
8	5	7R110020-13	02602	MATERIAL SAMPLES	VARIOUS	TBD		
1	4	7R110020-9	02602	INSULATION	FIBEFRAX PAPER	550 F, 4 LAYERS		
1	3	7R110020-7	02602	INSULATION, INNER	FIBERFRAX CERAMIC PAPER	550 F ONE LATER		
1	2	7R110020-5	02602	INSULATION, LINER	FIBERFRAX CERAMIC PAPER	550 K 4 LAYERS		
1	1	7R110020-3	02602	FILLER, CASTABLE, CERAMIC	CASTABLE CERAMIC	ZIRCORAM 90.02		
-	-	7R110020	02602	PLAIN LINER BRAZE ASSY OF			--	--

PARTS LIST

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125 MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES : ±0°30'
  - DECIMALS : .XX ±.03
    .XXX ±.010

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CONTRACT DE-FC26-04NT42237
CREATION DATE 05-04-15
RELEASE STAMP

BOEING Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

CASTING, PLAIN LINER, GASIFIER

SIZE E | CAGE CODE 02602 | DRAWING NO. 7R110020
SCALE 3/8 | SHEET 1 of 2

DESIGNED BY K. HUYNH
DWG NO. 7R110020 SH 1
PDM MODEL REV 1.27
PDM DRAWING REV 1.21

FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)

REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
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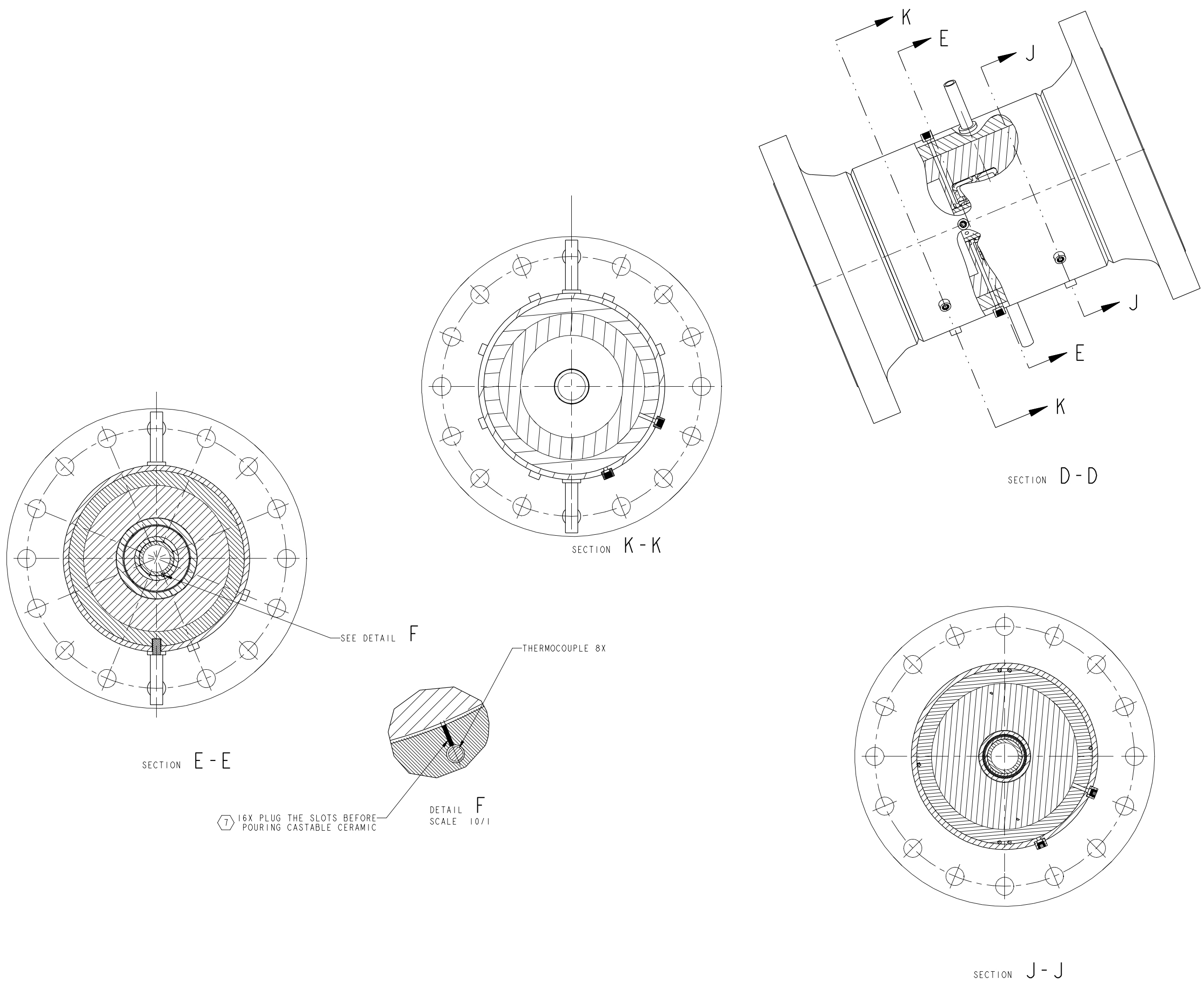
NOTE: UNLESS OTHERWISE SPECIFIED



ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

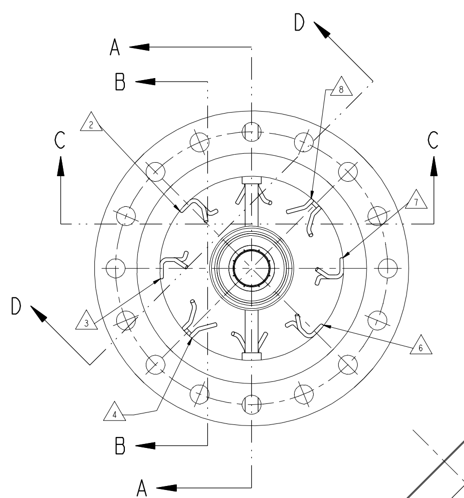
BOEING Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

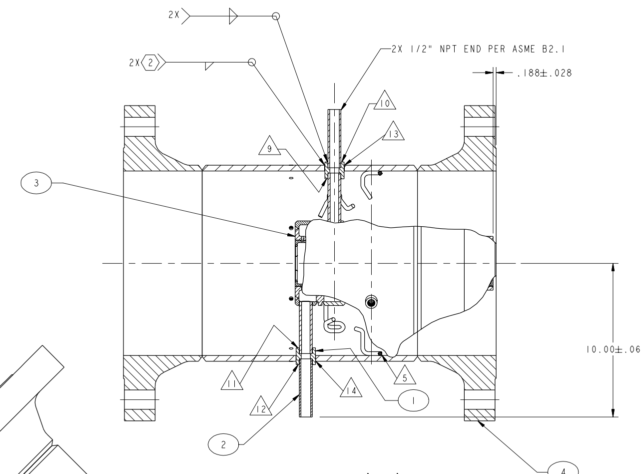
SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110020
SCALE 3/8		SHEET 2

DWG NO. 7R110020 SH 2

PDM MODEL REV 1.27
PDM DRAWING REV 1.21

FORM NO. R110-N-29 REV. 10-14-2000 (PRO/ENGINEER)





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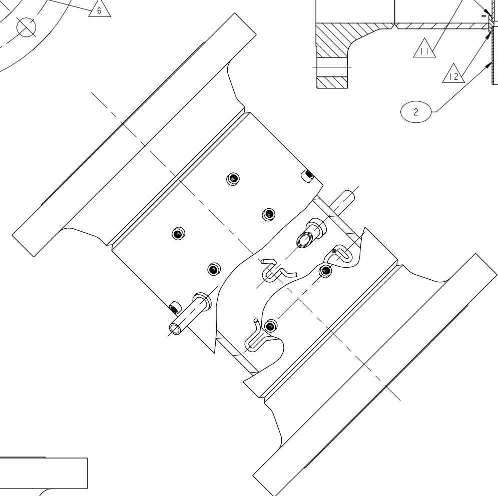

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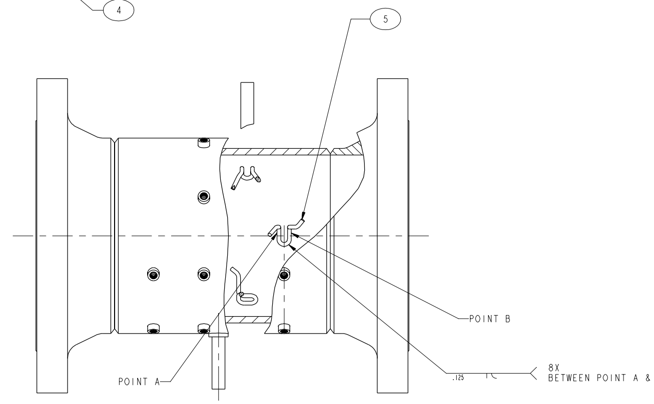
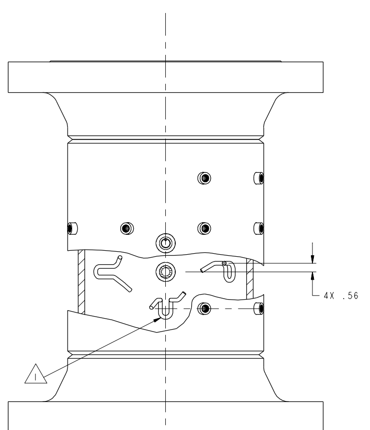


SECTION B-B



SECTION C-C

△ NO	LCTN
1	8B
2	8G
3	8F
4	8F
5	4F
6	7F
7	7G
8	7G
9	5G
10	4G
11	5F
12	5F
13	4G
14	5F

REVISIONS	ALL SHEETS SAME REV		
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED

1. DESIGN, FABRICATE AND EXAMINE TO THE REQUIREMENTS OF ASME B&PV CODE, SECTION VIII, DIV. 1, 2004 EDITION.
2. ASSEMBLE WITH CERAMIC FILLER TOOLING 7R110028 PRIOR TO WELDING COUPLING TO OUTER PIPE SHELL.
3. △ SYMBOL INDICATES JOINT IDENTIFY NUMBER.
4. MCMASTER-CARR, SANTA FE SPRING, CA 90670 ORI EQUIVALENT
5. HYDROSTATIC OR PNEUMATIC PRESSURE TEST, PRESSURIZING ITEM 4 AND OUTER SHELL INDEPENDENTLY
ANALYTICAL BURST PRESSURE = 4200 PSIG.
BURST ENERGY = 87,000 FT-LBS.
6. J.T.THORPE & SON. INC
LA MIRADA, CA 90638
7. PACKAGE PROTECTION PER RA0116-094, METHOD P-1.

QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION NOTES, SUPPLIERS	SH	ZONE
8	5	AR749	1DSC9	ANCHOR	304	AMS 5639 ⟨6⟩		
1	4	7R110030-1	02602	HOUSING, HX, GASIFIER ASSYOF	-	-		
1	3	7R110023D1	02602	PLAIN LINER MACHINED	-	-		
2	2	7R110021-3	02602	1/2" SCH 80S PIPE PER ASME B36.19	CRES 304	ASME SA 312 GRADE TP 304		
2	1	44965K454	3A054	1/2" 3000 LB SST COUPLING	304 CRES	ASME SA182 F304, ASME B16.11 ⟨4⟩		
-	-	7R110021	02602	PLAIN LINER WELDED ASSY OF			--	--

PARTS LIST

BOEING PROPRIETARY

EXPORT CONTROLLED

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125 MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES: ±0°30'
  - DECIMALS: .XX ±.03
    .XXX ±.010

DO NOT SCALE PRINT

CONTRACT DE-FC26-04NT42237
CREATION DATE 05-04-11
RELEASE STAMP

RELEASED DOCUMENT

APPROVALS ON RECORD

BOEING
Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

PLAIN LINER,
GASIFIER,
WELDED ASSY

SIZE E | CAGE CODE 02602 | DRAWING NO. 7R110021
SCALE 3/8 | SHEET 1 of 1

DWG NO. 7R110021 SH 1

DESIGNED BY H. HUYNH

PDM MODEL REV 1.12
PDM DRAWING REV 1.12

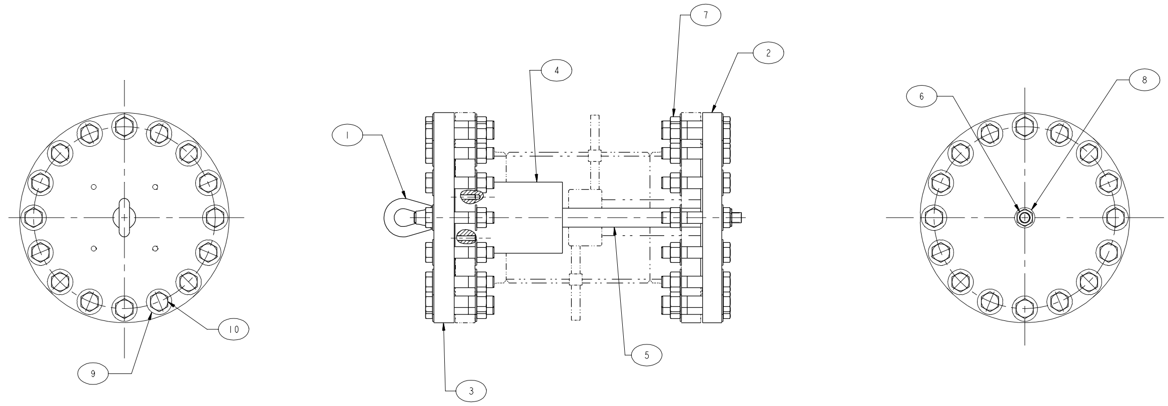
FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)

REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

REVISIONS — ALL SHEETS SAME REV

NOTE: UNLESS OTHERWISE SPECIFIED

1. MACHINE PER RA0103-016
2. SHALLOW ELECTROCHEMICAL ETCH IDENTIFY PER RA1104-003, TYPE IV ON PARTS -3 THRU -9.
3. CLEAN SHALL BE PERFORMED TO REMOVE OIL, SCALE, RUST, AND OTHER GENERAL CONTAMINATION FROM HARDWARE DURING AND AFTER MANUFACTURING PROCESS.



QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION NOTES, SUPPLIERS	SH	ZONE
32	10	92198A160	3A054	BOLT,HEX HD, 1-1/8-7 X 6" LG	18-8 CRES			
64	9	92141A039	3A054	WASHER,FLAT, #1-1/8, 18-8 CRES	18-8 CRES	COMMERCIAL		
2	8	92141A038	3A054	WASHER,FLAT, #1", 18-8 CRES	18-8 CRES	COMMERCIAL		
32	7	91845A039	3A054	NUT, HEX, 1-1/8"-7, CRES	18-8 CRES			
1	6	91845A038	3A054	NUT, HEX, 1"-8, CRES	18-8 CRES			
1	5	7R110028-9	02602	MOLD, HOLE	ALLOY STEEL	TBD		
1	4	7R110028-7	02602	MOLD CONE REPLACEABLE	ALUMINUM OR ALLOY STEEL	TBD		
1	3	7R110028-5	02602	FLANGE, INLET END	MADE FROM 12" 300# BLIND ALY STL FLG	TBD		
1	2	7R110028-3	02602	FLANGE, OUTLET END	MADE FROM 12" 300# BLIND ALY STL FLG	TBD		
1	1	3274T46	3A054	EYE NUT 1"-7	PLAIN STEEL	-		
-	-	7R110028	02602	TOOLING, FILLER, CASTABLE ASSY			--	--

PARTS LIST

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125/ MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES: ±0°30'
  - DECIMALS: .XX ±.03, .XXX ±.010

DO NOT SCALE PRINT

CONTRACT DE-FC26-04NT42237

CREATION DATE 05-04-08

RELEASE STAMP

RELEASED DOCUMENT

APPROVALS ON RECORD

BOEING — Rocketdyne, 6633 Canoga Avenue, Canoga Park, CA 91309-7922

TOOLING,CERAMIC FILLER, COOLED COUPON, GASIFIER

SIZE E | CAGE CODE 02602 | DRAWING NO. 7R110028

SCALE 1/4 | SHEET 1 of 3

DWG NO. 7R110028 SH 1

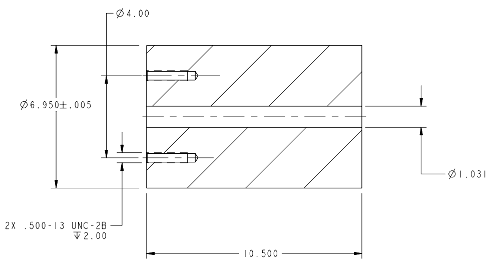
DESIGNED BY H. HUYNH

PDM MODEL REV 1.14
PDM DRAWING REV 1.13

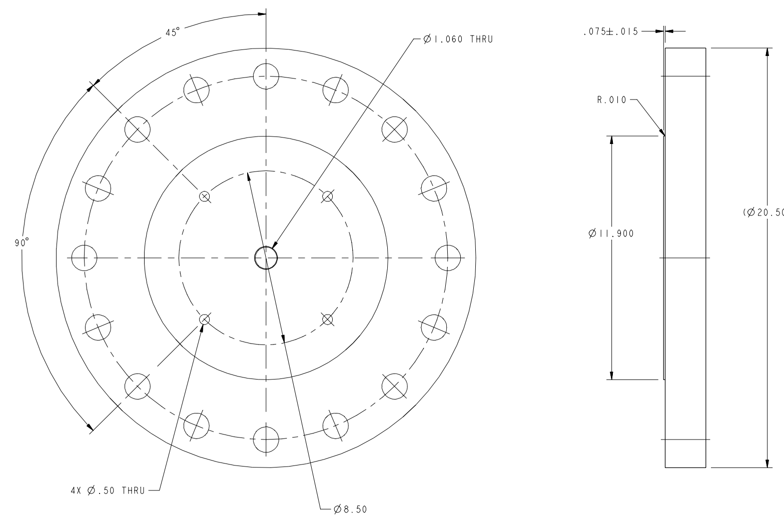
FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)

REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

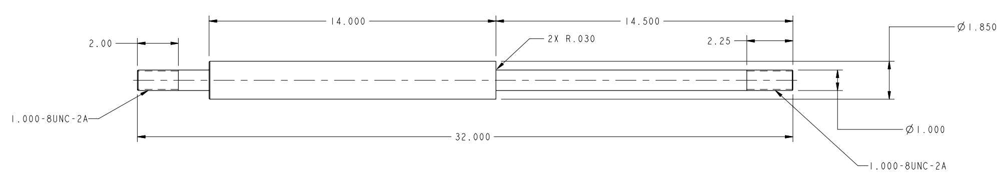
NOTE: UNLESS OTHERWISE SPECIFIED



-7 MOLD, CONE, REPLACEABLE



-5 FLANGE, INLET END
SCALE 1/2



-9 MOLD, HOLE
SCALE 1/2

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

RELEASED DOCUMENT

APPROVALS ON RECORD

BOEING Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

SIZE	CAGE CODE	DRAWING NO.	
E	02602	7R110028	
SCALE 1/4			SHEET 2

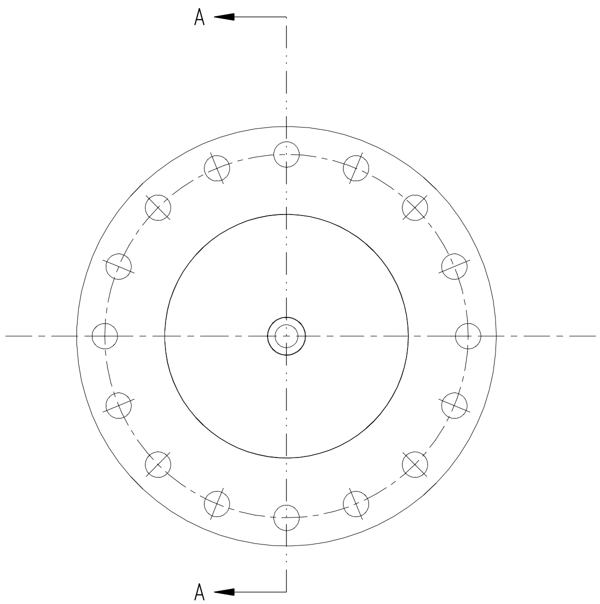
SH 2 DWG NO. 7R110028

PDM MODEL REV 1.14
PDM DRAWING REV 1.13

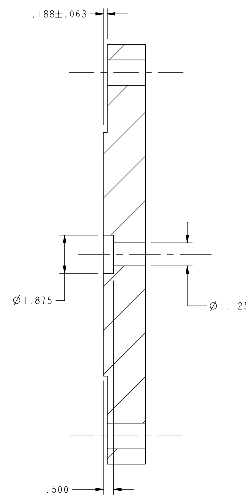
FORM NO. R110-N-29 REV. 10-16-2000 (PRO/ENGINEER)

REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED



-3 FLANGE OUTLET END
SCALE 1/2



SECTION A-A

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

RELEASED DOCUMENT
APPROVALS ON RECORD

BOEING
Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110028
SCALE 1/4		SHEET 3

DWG NO. 7R110028 SH 3

PDM MODEL REV 1.10
PDM DRAWING REV 1.13

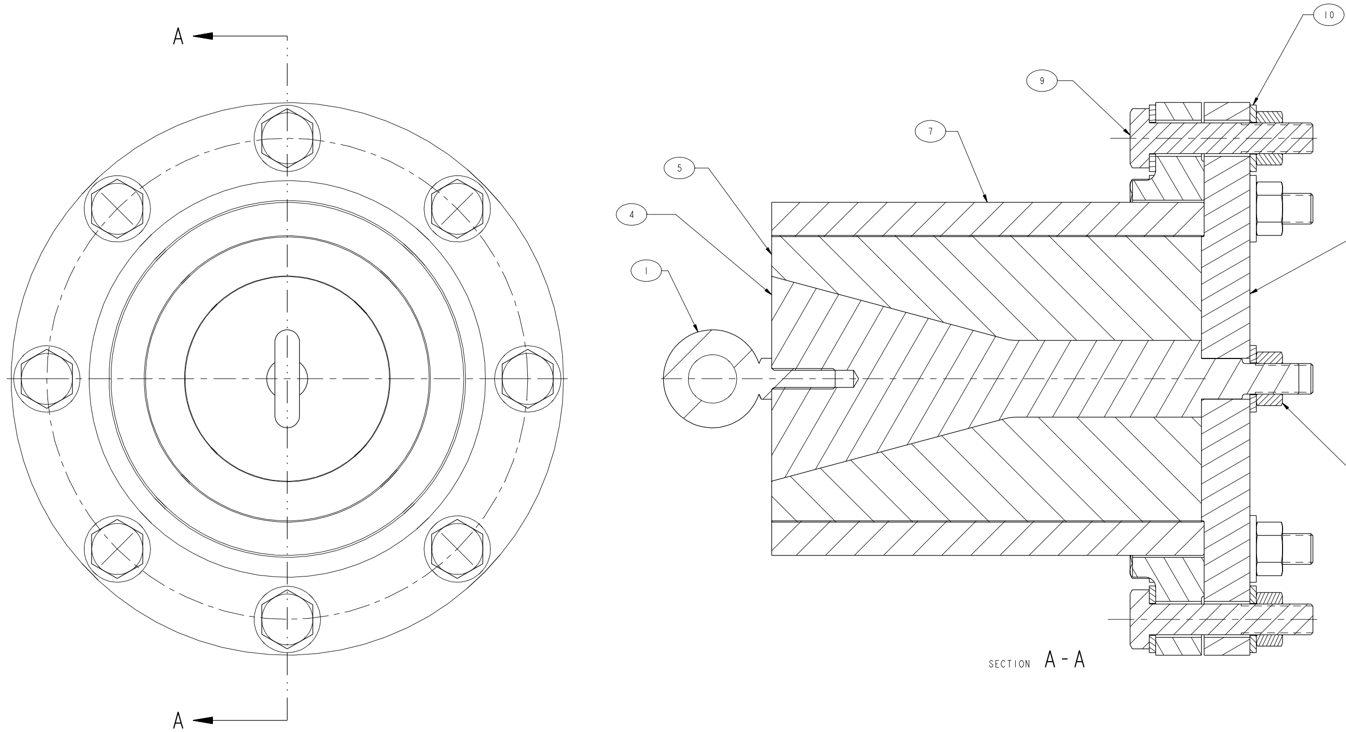
FORM NO. R110-N-29 REV. 10-16-2000 (PRO/ENGINEER)

REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

REVISIONS — ALL SHEETS SAME REV

NOTE: UNLESS OTHERWISE SPECIFIED

1. MACHINE PER RA0103-016
2. CLEAN SHALL BE PERFORMED TO REMOVE OIL, SCALE, RUST, AND OTHER GENERAL COMTAMINATION FROM HARDWARE DURING AND AFTER MANUFACTURING PROCESS.
3. WELD PER RA1607-098 , CLASS III
4. MCMASTER-CARR, SANTA FE SPRING, CA 90670 OR EQUIVALENT.
5. SHALLOW ECLECTROCHEMICAL ETCH IDENTIFY PER RF0004-044, TYPE IV



QTY REQD	QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION NOTES, SUPPLIERS	SH	ZONE
	17	10	98029A036	3A054	WASHER,FLAT,CASE HRD STEEL		4		
	8	9	94705A433	3A054	BOLT 3/4" x 3 1/2" GRADE B7	ALLOY STEEL	ASTM A193 4		
	9	8	91845A330	3A054	NUT, HEX, 3/4"-10, CRES	18-8 CRES	4		
	1	7	7R110029-11	02602	MOLD, CONE, OUTSIDE ASSY OF	-	-		
	1	6	7R110029-9	02602	8" 150# CS BLIND FLG	MADE FROM 8" 150# CS BLIND FLG	ASTM A105, ASME B16.5		
	1	5	7R110029-7	02602	CONE REPLACEABLE	CASTABLE CERAMIC	TBD		
	1	4	7R110029-5	02602	MOLD CONE INSIDE	CRES OR ALLOY STELL	TBD		
1		3	7R110029-3	02602	MOLD CONE OUTSIDE	MAKE FROM 8" SCH XXS PIPE	ASTM A53		
1		2	68095K233	3A054	8" 150# CS FLG	CS	ASTM A105, ASME B16.5 4		
		1	3014T491	3A054	EYEBOLT,THREADED,SHOULDER	PLAIN STEEL	4		
-11	-1	-	7R110029	02602	MOLD, REPLACEABLE CONE			--	--

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125 MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES : ±0°30'
  - DECIMALS : .XX ±.03, .XXX ±.010

DO NOT SCALE PRINT

CONTRACT DE-FC26-04NT42237

CREATION DATE 05-04-27

RELEASE STAMP

RELEASED DOCUMENT

APPROVALS ON RECORD

BOEING — Rocketdyne, 6633 Canoga Avenue, Canoga Park, CA 91309-7922

MOLD,CASTABLE CERAMIC REPLACEABLE CONE, GASIFIER

SIZE E | CAGE CODE 02602 | DRAWING NO. 7R110029

SCALE 1/1 | SHEET 1 of 3

DWG NO. 7R110029 | SH 1

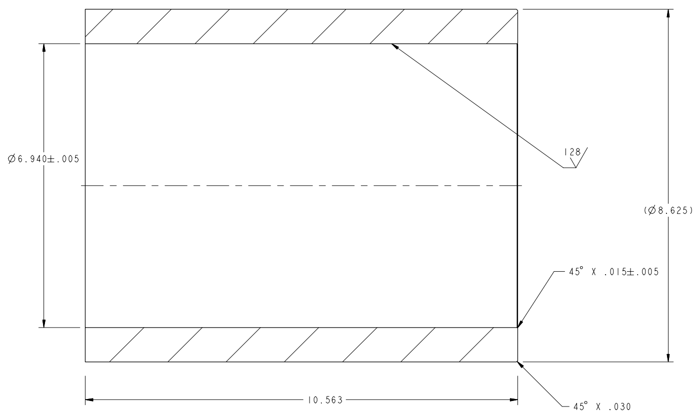
DESIGNED BY H. HUYNH

PDM MODEL REV 1.17
PDM DRAWING REV 1.17

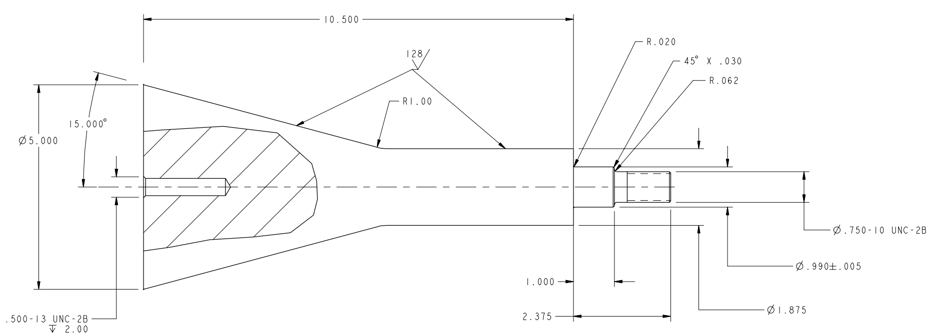
FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)

REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED



-3 MOLD CONE OUTSIDE



-5 MOLD CONE INSIDE

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

RELEASED DOCUMENT

APPROVALS ON RECORD

BOEING

Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110029

SCALE 1/1 SHEET 2

DWG NO. 7R110029 SH 2

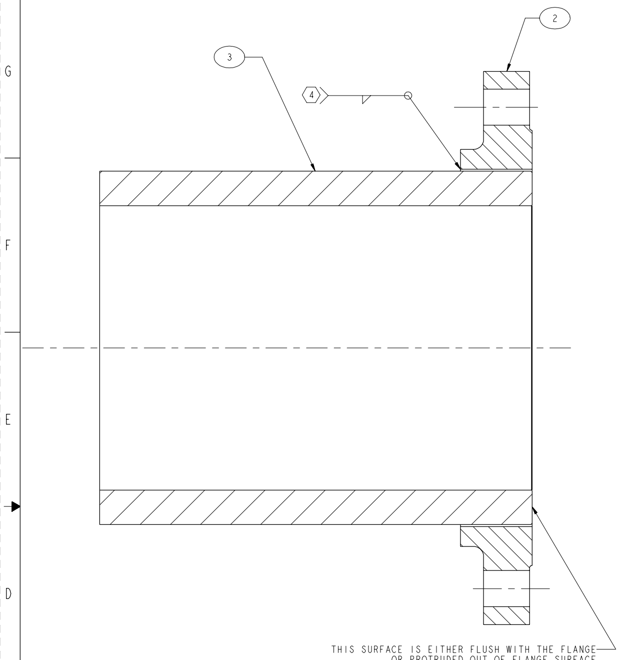
PDM MODEL REV 1.17
PDM DRAWING REV 1.17

FORM NO. R110-N-29 REV. 10-18-2000 (PRO/ENGINEER)

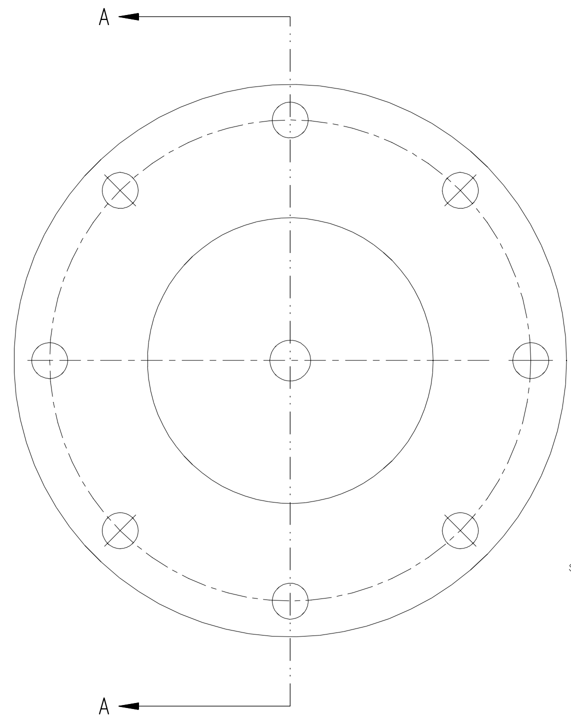
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

REVISIONS ALL SHEETS SAME REV

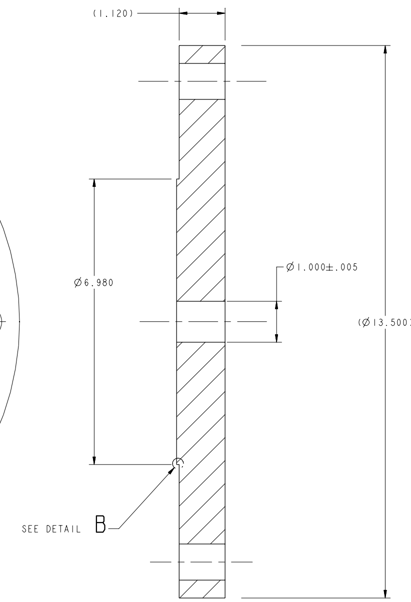
NOTE: UNLESS OTHERWISE SPECIFIED



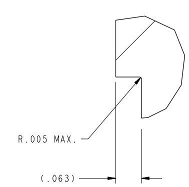
-11 MOLD OUTSIDE ASSY OF
SCALE: 1



-9 BLIND FLANGE
SCALE 1/1



SECTION A-A



DETAIL B
SCALE 10/1

RELEASED DOCUMENT
APPROVALS ON RECORD

ECCN: EAR99 NO LICENSE REQUIRED

BOEING PROPRIETARY

BOEING
Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

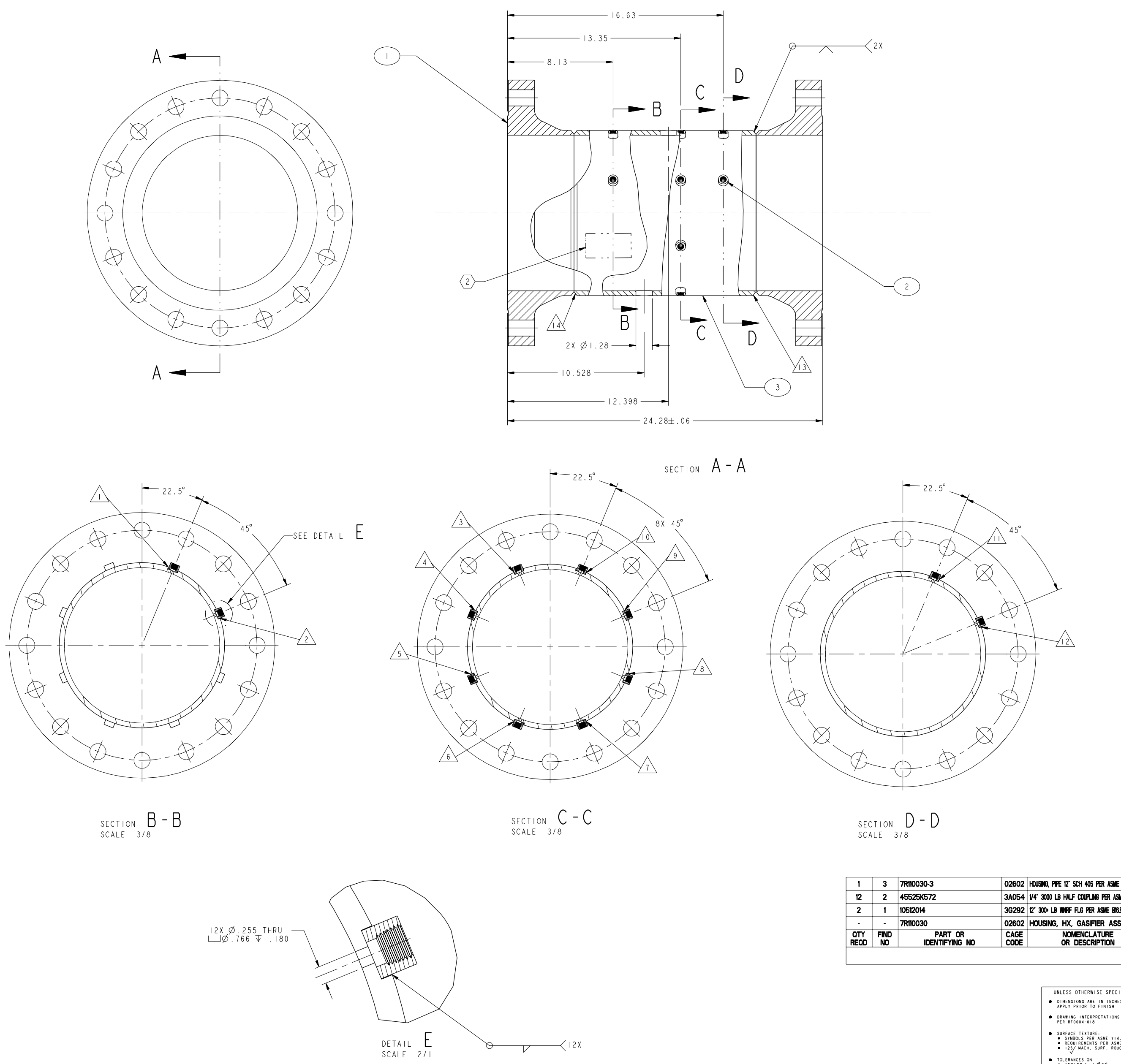
SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110029

SCALE 1/1 SHEET 3

DWG NO. 7R110029 SH 3

PDM MODEL REV 1.17
PDM DRAWING REV 1.17

FORM NO. R110-N-29 REV. 10-14-2000 (PRO/ENGINEER)



REVISIONS		ALL SHEETS SAME REV	
REV	DESCRIPTION	DATE	APPROVED
-	-	-	-

NOTE: UNLESS OTHERWISE SPECIFIED

1. DESIGN, FABRICATE AND EXAMINE TO THE REQUIREMENTS OF ASME B&PV CODE, SECTION VIII, DIV. 1, 2004 EDITION.
2. CODE STAMP IN ACCORDANCE WITH UG-115.
3. DESIGN REQUIREMENTS:
   MAWP = 265 PSIG.
   DESIGN TEMPERATURE = 1000°F.
   MINIMUM DESIGN TEMPERATURE = 32°F
   CORROSION ALLOWANCE = ZERO
   CONTRUCTION = WELD
   SERVICE = NON-LETHAL.
4. DUHIG & CO INC., LOS ANGELES, CA 90022 OR EQUIVALENT
5. MCMASTER-CARR, SANTA FE SPRINGS, CA 90670 OR EQUIVALENT.
6. △ SYMBOL INDICATES JOINT IDENTIFY NUMBER.

QTY REQD	FIND NO	PART OR IDENTIFYING NO	CAGE CODE	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION NOTES, SUPPLIERS	SH	ZONE
1	3	7R110030-3	02602	HOUSING, PIPE 12" SCH 40S PER ASME B36.19	CRES 304	ASME SA-312 GRADE TP304		
12	2	45525K572	3A054	1/4" 3000 LB HALF COUPLING PER ASME B16.5	CRES 304	ASME B16.11, ASME SA-182 GRADE F304 ⟨5⟩		
2	1	10512014	3G292	12" 300# LB WNRF FLG PER ASME B16.5	CRES 304	ASME B16.5, SA-182 GRADE F304 ⟨4⟩		
-	-	7R110030	02602	HOUSING, HX, GASIFIER ASSYOF			--	--

PARTS LIST

UNLESS OTHERWISE SPECIFIED:
- DIMENSIONS ARE IN INCHES AND APPLY PRIOR TO FINISH
- DRAWING INTERPRETATIONS PER RF0004-018
- SURFACE TEXTURE:
  - SYMBOLS PER ASME Y14.36
  - REQUIREMENTS PER ASME B46.1
  - 125√ MACH. SURF. ROUGHNESS
- TOLERANCES ON
  - ANGLES: ±0°30'
  - DECIMALS: .XX ±.03
    .XXX ±.010

DO NOT SCALE PRINT

CONTRACT DE-FC26-04NT42237
CREATION DATE 05-04-13
RELEASE STAMP
RELEASED DOCUMENT
APPROVALS ON RECORD

BOEING
Rocketdyne
6633 Canoga Avenue
Canoga Park, CA 91309-7922

HOUSING, HEAT EXCHANGER, GASIFIER

SIZE	CAGE CODE	DRAWING NO.
E	02602	7R110030

SCALE 3/8 SHEET 1 of 1

ECCN: EAR99 NO LICENSE REQUIRED TO CANADA

DESIGNED BY H. HUYNH

SH 1 DWG NO. 7R110030

PDM MODEL REV 1.29
PDM DRAWING REV 1.22

FORM NO. R110-N-4 REV. 10-14-2000 (PRO/ENGINEER)